High-Directivity Effects in Artificial Materials

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As is well known, periodic structures made of metallic and/or dielectric elements embedded in a uniform host medium may be represented, under suitable frequency ranges, as homogeneous artificial materials (metamaterials) which show novel and interesting electromagnetic features. One of these features is the creation of highly-directive radiation beams from simple sources such as dipoles.

In this study we investigate grounded slabs made of such metamaterials, excited by a horizontal electric or magnetic dipole placed inside the slab or on the ground plane, respectively. The media are represented through frequency-dependent constitutive parameters; using metamaterials with various combinations of low or high permittivity and permeability is considered, in order to achieve a high characteristic-impedance contrast with free space. This allows for the design of planar antennas with a very high directivity at broadside and a circularly symmetrical main beam. Some examples of artificial materials synthesized from periodic inclusions in a homogeneous host slab will be given to show that the design principles learned from the homogeneous metamaterial case may be applied to a design using an actual periodic metamaterial.

Furthermore, an interpretation of the high-directivity effect is provided in terms of the excitation of leaky waves with small phase and attenuation constants that are supported by the grounded metamaterial slabs. The frequency bandwidth of this class of antennas is studied, and design formulas for maximizing the radiated power density at broadside are derived. We also examine the role of the direct space wave radiated by the elementary source and show how this radiation component compares to the radiation from the leaky-wave field.